DoD Current State for Software Technology Readiness Assessments

Systems & Software Technology Conference
April 2010

Cynthia Dion-Schwarz, Ph.D.
Director, Information Systems & Cyber Security
Office of the Director, Defense Research and Engineering
Research Directorate

		Form Approved OMB No. 0704-0188
	Report Documentation Page	

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1. REPORT DATE **APR 2010**	2. REPORT TYPE	3. DATES COVERED **00-00-2010 to 00-00-2010**

4. TITLE AND SUBTITLE **DoD Current State for Software Technology Readiness Assessments**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Office of the Director, Defense Research and Engineering,Information Systems & Cyber Security,Washington,DC,20301**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
Presented at the 22nd Systems and Software Technology Conference (SSTC), 26-29 April 2010, Salt Lake City, UT.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**17**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Introduction

- ***Technology Readiness Levels* are a scale that describes the maturity of a technology with respect to a particular use**
  - Scale from 1 (least mature) to 9 (most mature)
  - Heuristics:
    - TRL 1 = "an idea"
    - TRL 4 = "a software mock-up"
    - TRL 6 = "a prototype that has completed beta testing"
    - TRL 7 = "ready for operational testing, technical work complete"
    - TRL 9 = "fielded and used as intended"

To establish a TRL value, an understanding of BOTH the accomplishments and the intended use of the technology is required

Technology Readiness Assessments are Narrow in Scope

- **Primary Purpose: to help <u>management make decisions</u> concerning the development and transition of technology.**
- **Uses of Technology Readiness Levels (TRLs):**
  - Provides a common understanding of technology status (maturity)
  - Conveys what has been accomplished (demonstrated) with the technology
  - Used as a factor in technical risk management
  - Used to make decisions concerning technology funding
  - Used to make decisions concerning transition of technology
  - Used to scope acquisition programs and their requirements
  - Used as a basis for certification under statute
- **Other risk-related technical measures are also important:**
  - Performance envelope of the technology – where does the technology break?
  - Difficulty of work to be done – can the technology be matured?
  - Systems Design – is the design good?
  - Systems engineering and systems integration – are the system design objectives met?
  - Appropriateness of the technology – is it the best choice?

The TRL value does not indicate that the technology is right for the job or that application of the technology will result in successful development of the system

Technology Readiness Assessments (TRAs): Historical Perspective

- "Program managers' ability to reject immature technologies is hampered by

  (1) untradable requirements that force acceptance of technologies despite immaturity, and

  (2) reliance on tools that fail to alert managers of high risks that would prompt rejection."

  GAO/NSIAD-99-162

- "Identify each case in which a major defense acquisition program entered system development and demonstration … into which key technology has been incorporated that does not meet the technology maturity requirement … and provide justification for why such key technology was incorporated and identify any determination of technological maturity with which the Deputy Under Secretary of Defense for Science and Technology did not concur and explain how the issue has been resolved."

  National Defense Authorization Act for Fiscal Year 2002

- "The management and mitigation of technology risk, which allows less costly and less time-consuming systems development, is a crucial part of overall program management and is especially relevant to meeting cost and schedule goals. Objective assessment of technology maturity and risk shall be a routine aspect of DoD acquisition."

  DoDI 5000.2, paragraph 3.7.2.2

> *Aim: To stop launching acquisition programs before technologies are mature!*

Defense Acquisition Framework

Prerequisites for new programs:

- Validated operational requirement
- Technology/acquisition readiness
- Identified funding resources

> **Technology Readiness Levels are one indicator of readiness to commence succeeding stages of acquisition**

Changes to Statute

10 USC §2366b states

Major defense acquisition programs: certification required before Milestone B or Key Decision Point B approval:

(a) CERTIFICATION. A major defense acquisition program may not receive Milestone B approval, or Key Decision Point B approval in the case of a space program, until the milestone decision authority certifies that [the MDA]–

. . .

(2) has received the results of the preliminary design review and conducted a formal post-preliminary design review assessment, and certify on the basis of such assessment that the program demonstrates a high likelihood of accomplishing its intended mission

. . .

(3)(D) the technology in the program has been demonstrated in a relevant   environment as determined by the Milestone Decision Authority on the basis of an independent review and assessment by the Director of Defense Research and Engineering;
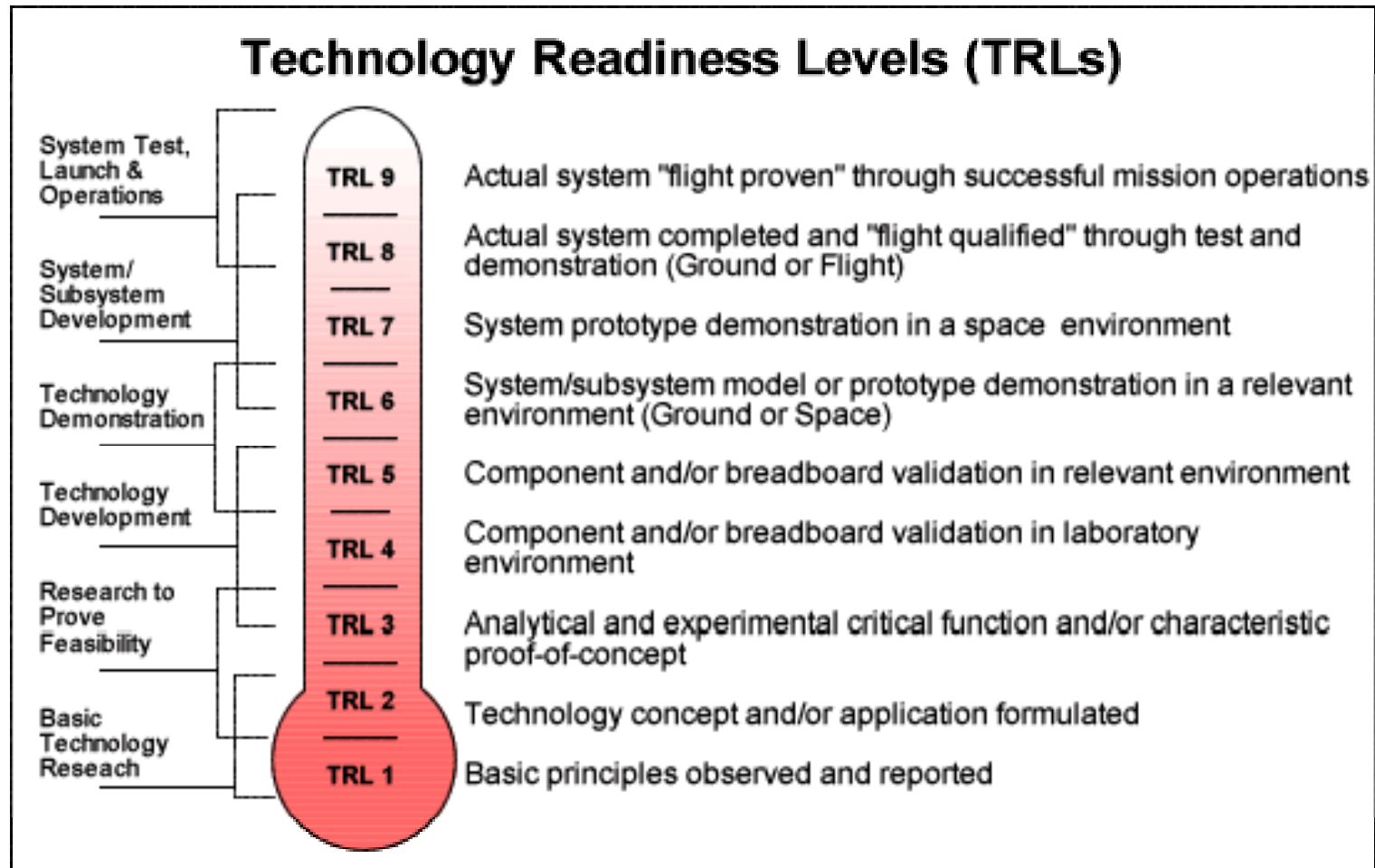
. . .

(3)(E) the program complies with all relevant policies, regulations and directives of the Department of Defense

In addition, P.L. 111-23 (WSARA) amended Title 10 (139 a(c)(2) of title 10) to require DDR&E to directly report TRA findings annually to the Congress

All technologies in large programs must be TRL 6 or better as determined by DDR&E unless waived by the MDA for national security reasons

Technology Readiness Levels (TRLs)

System Test, Launch & Operations	TRL 9	Actual system "flight proven" through successful mission operations
System/ Subsystem Development	TRL 8	Actual system completed and "flight qualified" through test and demonstration (Ground or Flight)
	TRL 7	System prototype demonstration in a space environment
Technology Demonstration	TRL 6	System/subsystem model or prototype demonstration in a relevant environment (Ground or Space)
Technology Development	TRL 5	Component and/or breadboard validation in relevant environment
	TRL 4	Component and/or breadboard validation in laboratory environment
Research to Prove Feasibility	TRL 3	Analytical and experimental critical function and/or characteristic proof-of-concept
Basic Technology Reseach	TRL 2	Technology concept and/or application formulated
	TRL 1	Basic principles observed and reported

Department of Defense Hardware TRLs

Increasing maturity →

1. **Basic principles observed and reported**

2. **Technology concept and/or application formulated**

3. **Analytical and experimental critical function and/or characteristic proof of concept**

4. **Component and/or breadboard validation in a laboratory environment**

5. **Component and/or breadboard validation in a relevant environment**

6. **System/subsystem model or prototype demonstration in a relevant environment**

7. **System prototype demonstration in an operational environment**

8. **Actual system completed and qualified through test and demonstration**

9. **Actual system proven through successful mission operations**

Department of Defense Software TRLs

Increasing maturity

1. **Basic principles observed and reported.**
2. **Technology concept and/or application formulated.**
3. **Analytical and experimental critical function and/or characteristic proof of concept**
4. **Module and/or subsystem validation in a laboratory environment, i.e. software prototype development environment**
5. **Module and/or subsystem validation in a relevant environment**
6. **Module and/or subsystem validation in a relevant end-to-end environment**
7. **System prototype demonstration in an operational high fidelity environment**
8. **Actual system completed and mission qualified through test and demonstration in an operational environment**
9. **Actual system proven through successful mission proven operational capabilities**
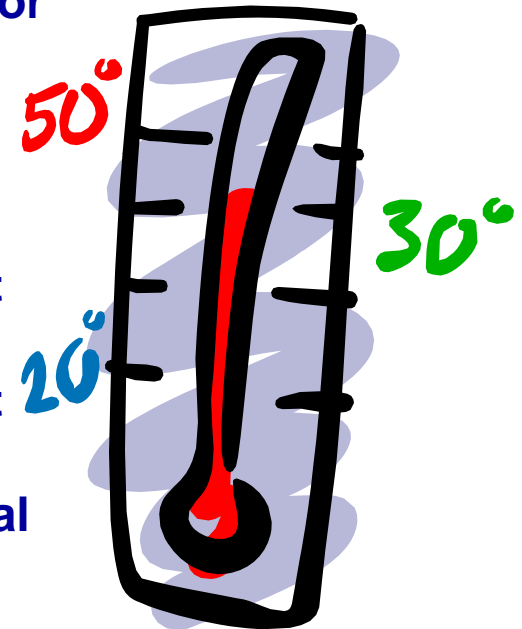
Definition and Purpose: Technology Readiness Assessment (TRA)

- **DoD Requires all programs to conduct a TRA before commencing Engineering, Manufacturing Design Development (that is, at Milestone B)**

TRA Definition:

Systematic, metrics-based process and accompanying report

- **Assesses the maturity of Critical Technology Elements (CTEs) used in systems**
- **Uses Technology Readiness Levels (TRLs) as the metric**
  - Adequate maturity at MS B (TRL 6 or greater) is largely based on experience with prototypes or previous usage in a relevant environment
- **Report includes**
  - how the CTEs are identified,
  - why CTEs are important to the program, and
  - an *independent* (from the program) assessment of their maturity

DoD uses the TRA as the basis for the certification to Congress
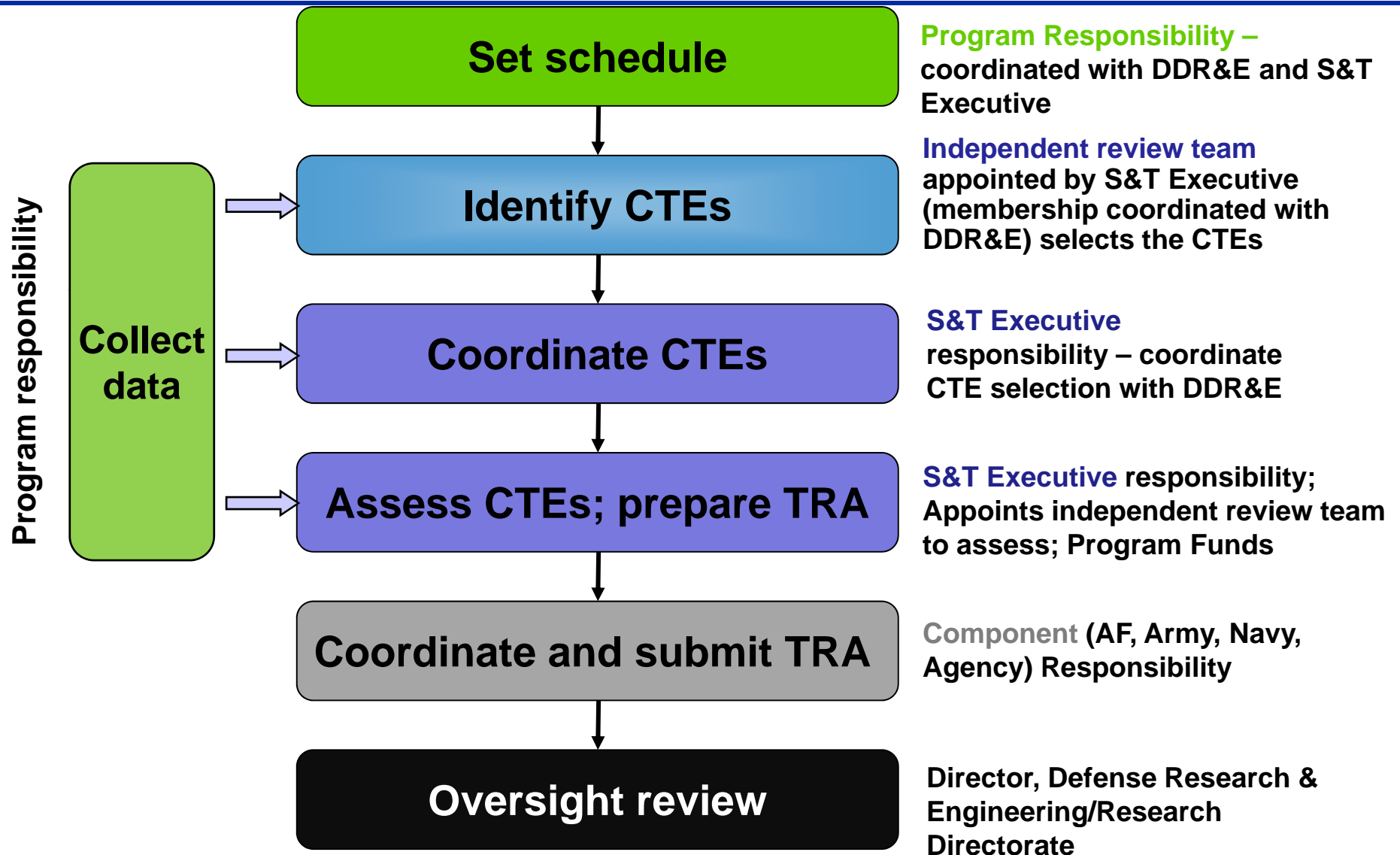
Critical Technology Elements

A technology element is "critical" if the system being acquired depends on this technology element to meet its operational requirements (within acceptable cost and schedule limitations) and if the *technology element or its application* is either *new or novel* or in an area that poses *technological risk* during detailed design or demonstration.

- **Software CTEs can be new developments (new or novel) or COTs/GOTs (new or novel applications)**

- **Software CTEs – and programs – typically stumble over the evaluation of the *environment* in which it will be employed – although COTs may be commonly used commercially, the DoD operational and technical environment is often different from the commercial environment (think, e.g., the technical security environment**

Architectures/Design and test data usually need to identify and evaluate software CTEs with confidence

TRA Process Overview

Program responsibility

Collect data

Process	Responsibility
Set schedule	**Program Responsibility –** coordinated with DDR&E and S&T Executive
Identify CTEs	**Independent review team** appointed by S&T Executive (membership coordinated with DDR&E) selects the CTEs
Coordinate CTEs	**S&T Executive** responsibility – coordinate CTE selection with DDR&E
Assess CTEs; prepare TRA	**S&T Executive** responsibility; Appoints independent review team to assess; Program Funds
Coordinate and submit TRA	**Component** (AF, Army, Navy, Agency) Responsibility
Oversight review	**Director, Defense Research & Engineering/Research Directorate**

TRA Execution

1. Independent Review Team identifies the CTEs by looking across the established program **Work Breakdown Structure** (**WBS**) or **Systems Architecture** for technology components essential to the system and are either new or novel, are being applied in a new or novel way, or are otherwise important to the program
2. Data concerning the performance of the CTEs are collected and presented to reviewers independent from the program and expert in the technologies
3. Independent reviewers assess maturity of CTEs against established TRL metrics
4. Assessment is approved by the Service or Agency Science & Technology Executive and forwarded to the **Component Acquisition Executive** (**CAE**) or Agency Head, who then transmits it to the **Research Directorate, DDR&E**
5. **Director of Research** concurs with the TRA, concurs with reservation, or does not concur
   - Director of Research may elect to conduct his own assessment
   - If Director of Research does not concur, TRA is returned to the Service or Agency for changes or election to conduct another independent TRA
   - In all cases, DDR&E/Research forwards recommendations to the **Milestone Decision Authority** (**MDA**) as input to the acquisition decision process

> *If all technologies are TRL 6, then DDR&E recommends certification*

Other Outcomes are possible

When the Technologies are not all TRL 6:

– The program is re-structured to use only mature technologies

– The program start is delayed to mature the technologies

– The requirements for the program are modified

– DoD may grant a waiver for national security reasons

– The program is never initiated and a different solution is sought

DoD Uses TRLs to help scope programs and their requirements

Current Emphasis

- **DoD has recently updated the TRA Policy**
- **Past experiences suggest that for good outcomes:**
  - Sound Systems Engineering/Design used as a basis for CTE identification
  - An early start to understanding the technologies and the requirements
  - Prototyping before program start
  - Technology maturity guiding requirements development
  - *Independence* and *Expertise* of the assessors
  - Selection of the *CTEs* to be assessed
  - Assessments folded into risk management
  - Additional technical assessments (design reviews, manufacturability, e.g.)
  - Frequent explanations of TRAs (training) across the DoD community

Current update incorporates many lessons and reflect certification requirements

Reference:

Technology Readiness Assessment (TRA) Deskbook (July 2009)

- Hardware Technology Readiness Levels

- Software Technology Readiness Levels

- Biometrics Technology Readiness Levels

- Manufacturing Technology Readiness Levels (MRLs)

http://www.defenselink.mil/ddre/doc/tra_deskbook_2009.pdf

TRA Deskbook Guidance Developed by OSD/DDR&E/RD

- Mr. Jack Taylor, jack.taylor@osd.mil

- Mr. David Jakubek, david.jakubek@osd.mil

- Dr. Cynthia Dion-Schwarz, cynthia.dion-schwarz@osd.mil

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TRL Definitions

- **BREADBOARD:** Integrated components that provide a representation of a system/subsystem and which can be used to determine concept feasibility and to develop technical data. Typically configured for laboratory use to demonstrate the technical principles of immediate interest. May resemble final system/subsystem in function only.

- **"HIGH FIDELITY":** Addresses form, fit and function. High fidelity laboratory environment would involve testing with equipment that can simulate and validate all system specifications within a laboratory setting.

- **"LOW FIDELITY":** A representative of the component or system that has limited ability to provide anything but first order information about the end product. Low fidelity assessments are used to provide trend analysis.

- **MODEL:** A reduced scale, functional form of a system, near or at operational specification. Models will be sufficiently hardened to allow demonstration of the technical and operational capabilities required of the final system.

- **OPERATIONAL ENVIRONMENT:** Environment that addresses all of the operational requirements and specifications required of the final system to include platform/packaging.

- **PROTOTYPE:** The first early representation of the system which offers the expected functionality and performance expected of the final implementation. Prototypes will be sufficiently hardened to allow demonstration of the technical and operational capabilities required of the final system.

- **RELEVANT ENVIRONMENT:** Testing environment that simulates the key aspects of the operational environment.

- **SIMULATED OPERATIONAL ENVIRONMENTAL:** Environment that can simulate all of the operational requirements and specifications required of the final system or a simulated environment that allows for testing of a virtual prototype to determine whether it meets the operational requirements and specifications of the final system.